

GEO-CAPE Aerosol Working Group Report

GSFC AeroCenter Update, May 31, 2013

AWG members of FY13:

NASA GSFC	Mian Chin, Hiren Jethva, Joanna Joiner, Alexei Lyapustin, Shana Mattoo, Omar Torres, Alexander Vasilkov
NOAA NESDIS	Shobha Kondragunta, Pubu Ciren
UMBC	Lorraine Remer
U Nebraska Lincoln	Jun Wang

GEOSTATIONARY COASTAL AND AIR POLLUTION EVENTS (GEO-CAPE)

- Decadal Survey mission
- Atmosphere and coastal ocean components
- Atmosphere science questions focusing on:
 - **Emission:** trace gases and aerosols
 - **Process:** urban to continental, diurnal to seasonal
 - **Climate forcing and air quality:** interactions
 - **Societal benefit:** observation to improve AQ forecast
 - **Transport:** long-range transport affecting AQ
 - **Episodic events:** wild fires, dust storms, volcanic eruptions
- Key species/quantities measured:
 - Gases: UV-Vis: O_3 , NO_2 , SO_2 , HCHO, CHOCHO; IR: CO, CH_4 , NH_3
 - Aerosol: UV-Vis: AOD, AAOD, AI, AOCH, 1x1 km pixel resolution
- Observation domain and frequency:
 - Domain: North America
 - Frequency: Hourly

GEO-CAPE WILL MEASURE A SUITE OF SHORT-LIVED SPECIES THAT ARE RELEVANT TO BOTH AIR QUALITY AND CLIMATE

WITH THE EVI SELECTION OF TEMPO, THE PICTURE HAS CHANGED...

- TEMPO – Tropospheric emissions: Monitoring of pollution (PI: Kelly Chance, Harvard Smithsonian AO)
- Same science questions as GEO-CAPE
- UV-VIS instrument, 300 nm to >700 nm, on commercial geostationary satellite (“hosted payload”)
- Estimated launch time: 2019, being a part of “geostationary constellation” with Sentinel-4 over Europe and GEMS over Asia
- Key species/quantities measured:
 - Gases: O_3 , NO_2 , SO_2 , HCHO, CHOCHO
 - Aerosol: AOD, AAOD, AI, 4.5 (EW) x 2 (NS) km pixel resolution
- Now, in light of TEMPO selection, the aerosol related questions are:
 - Can GEO-CAPE aerosol science objectives and measurement requirements be met by TEMPO?
 - With TEMPO selection, what is left for GEO-CAPE?

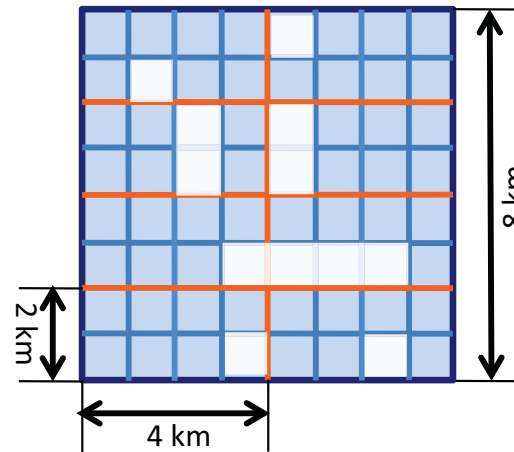
GEO-CAPE Aerosol Working Group high priority tasks, FY13

Task	Personnel
<i>High priority tasks:</i>	
H1. Availability of aerosol retrieval at TEMPO pixel resolution with MODIS cloud masks	Lorraine Remer, Shana Mattoo
H2. Aerosol retrieval availability and product quality at TEMPO vs. GEO-CAPE pixel resolution with the cloud mask at the same pixel resolution	Omar Torres, Hiren Jethva, Shana Mattoo
H3. Feasibility of TEMPO-GOES-R synergistic retrieval: (a) expanded spectral range from UV (TEMPO) and SWIR (GOES-R), (b) with high resolution cloud mask (1-km GOES-R) for TEMPO, and (c) feasibility of multi-angle retrieval	(1) NESDIS group: Shobha Kondragunta, Pubu Ciren (2) GSFC group: Alexei Lyapustin (3) UNL group: Jun Wang
H4. Feasibility of retrieving aerosol layer height with O ₂ -B (688 nm) and O ₂ -γ (628 nm) bands	Alexander Vasilkov, Joanna Joiner

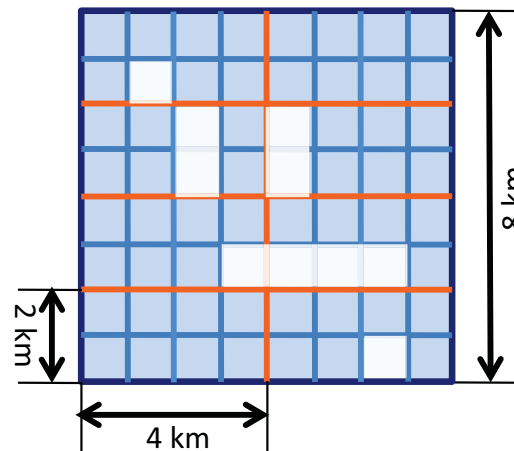
AOD RETRIEVAL AVAILABILITY AND AOD QUALITY – GEO-CAPE VS. TEMPO

H1. TEMPO aerosol retrieval availability (Lorraine Remer, Shana Mattoo)

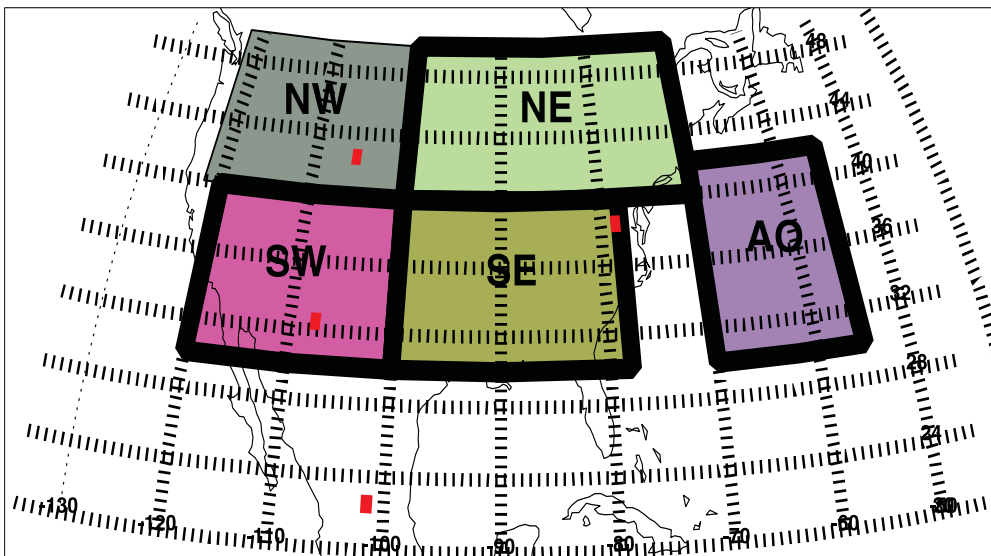
- Using MODIS 0.5-km cloud mask for aerosol retrieval to test the aerosol retrieval availability in CONUS at sensor resolutions at **1x1 (GEO-CAPE)**, 2x2, 4x4, 8x8, 4(EW)x1(NS), and **4(EW)x2(NS) km (TEMPO-like)**
- Product size at 8x8 km
- 5 regions



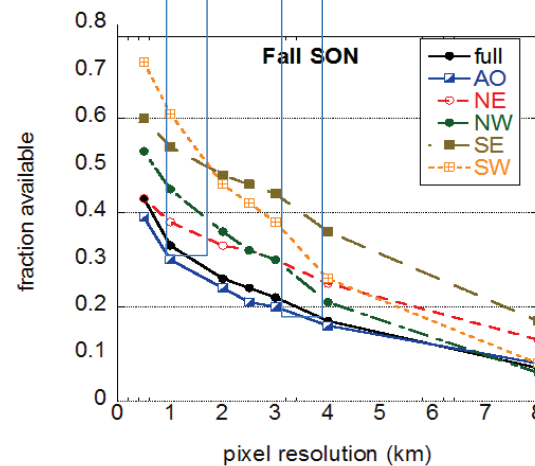
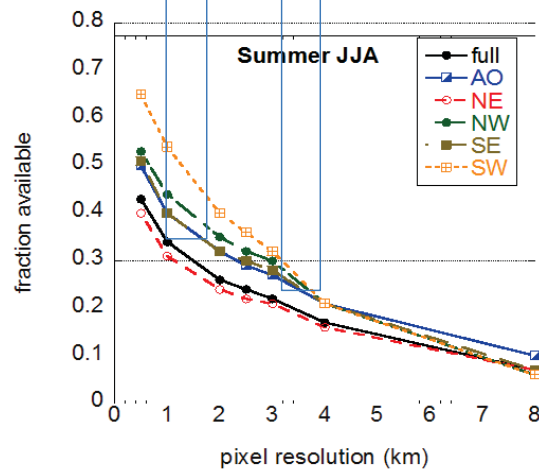
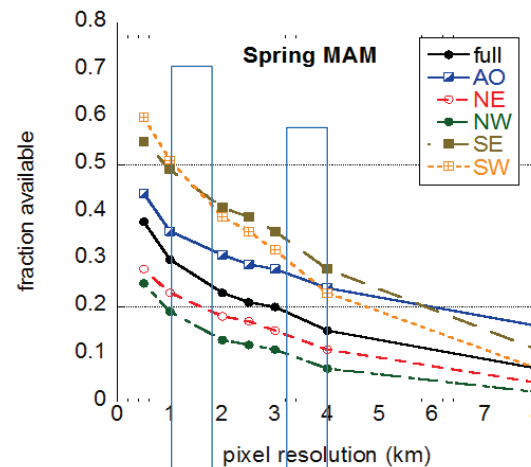
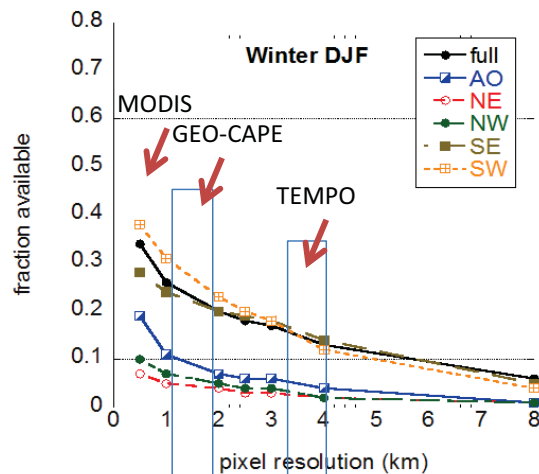
In this case, “GEO-CAPE” (1x1km) will be able to retrieve AOD but “TEMPO” (4x2km) will not



In this case, both “GEO-CAPE” and “TEMPO” will be able to retrieve AOD



H1. TEMPO aerosol retrieval availability – Results



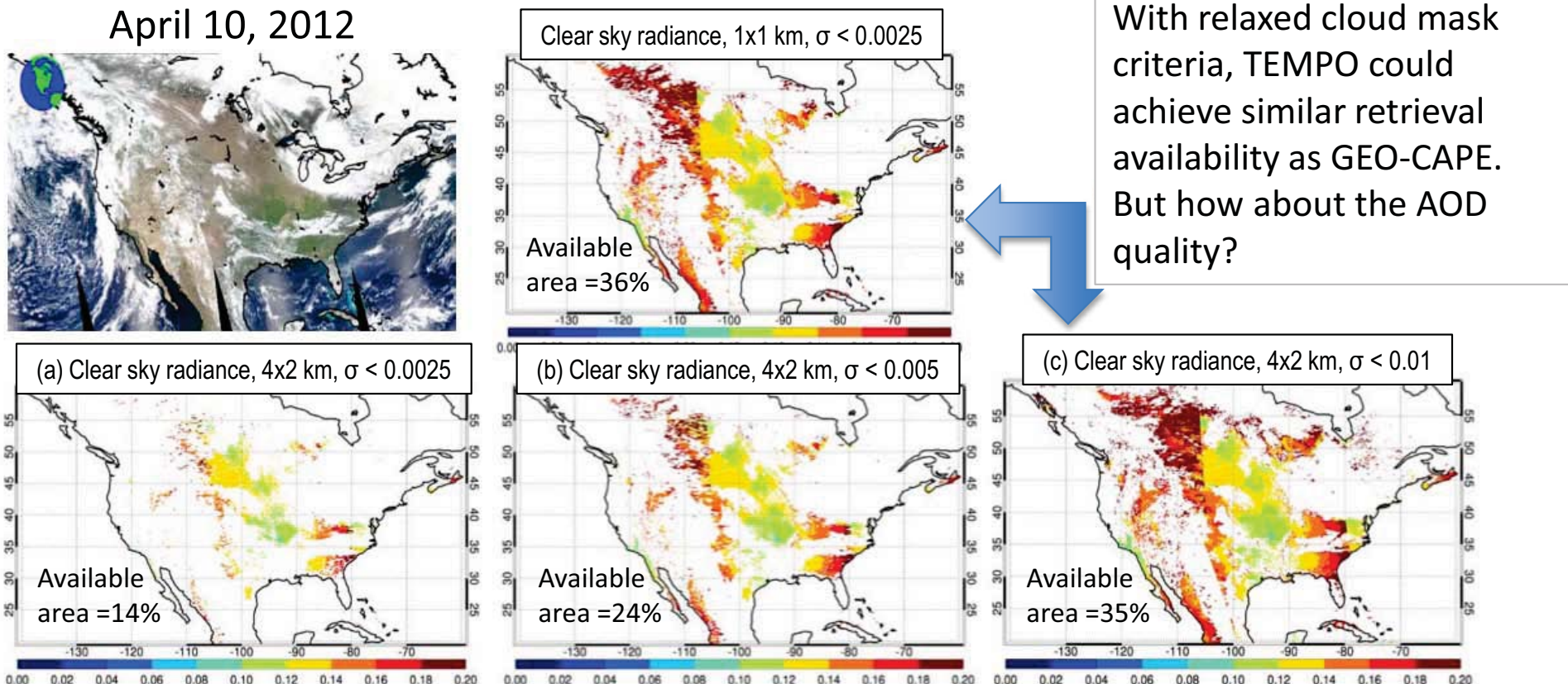
Regional statistics, 1x1 km (GEO-CAPE) and 4x2 km (TEMPO):

- TEMPO would have about 55% of the retrievals that MODIS provides now
- TEMPO will have about 2/3 retrieval availability of GEO-CAPE (1x1 km)

H2. Aerosol retrieval availability and product quality at TEMPO and GEO-CAPE resolution (own cloud mask) (Omar Torres, Hiren Jethva)

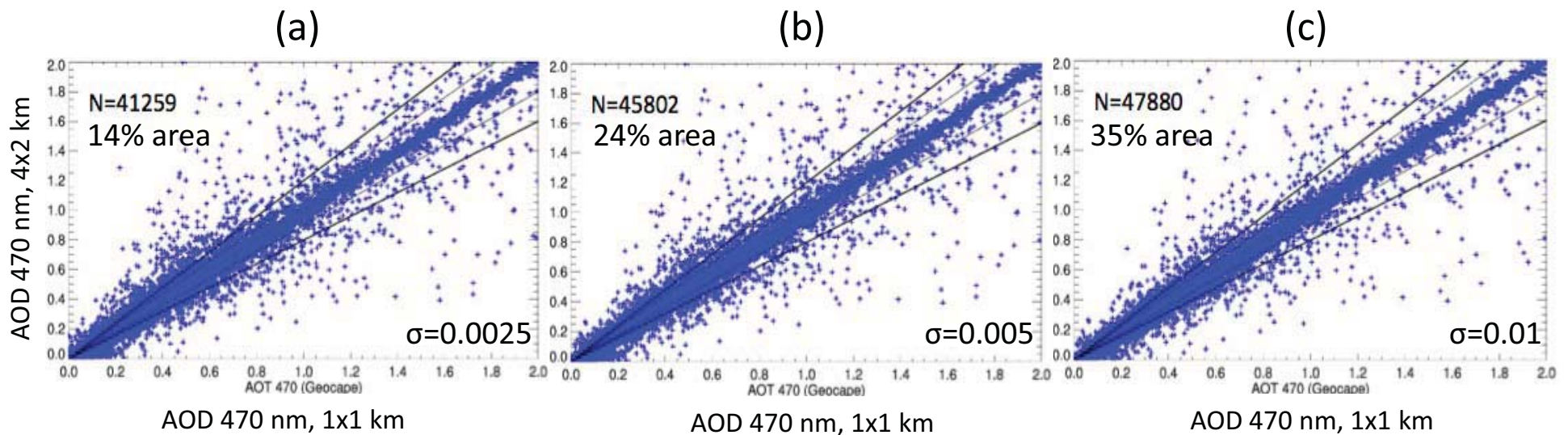
- Start with MODIS 0.5 km radiance data
- Generate 1x1 km cloud mask for GEO-CAPE with spatial variability (standard deviation) of reflectance $\sigma > 0.0025$ (MODIS criteria)
- Generate 4x2 km cloud mask for TEMPO with (a) $\sigma > 0.0025$, (b) $\sigma > 0.005$, (c) $\sigma > 0.01$
- Product size = 8 x 8 km

April 10, 2012



H2. Results – AOD relative quality

Comparisons between 8x8 km AOD product from “GEO-CAPE” 1x1 km (x-axis) and “TEMPO” 4x2 km (y-axis) retrieval with different cloud mask criteria for April 10, 2012:



- From the preliminary results, it does not seem that the quality of AOD from more relaxed cloud mask (thus higher probability of cloud contamination) is worse than that from more strict cloud mask. The spatial coverage from relaxed cloud mask is increased from strict to more relaxed cloud mask (20% increase of then number of 8x8 km aerosol products from a to c). HOWEVER, MORE STUDY IS NEEDED TO COLLECT SUFFICIENT STATISTICS AND TO COMPARE WITH AERONET DATA.

**TEMPO AND GOES-R SYNERGY – USE 2.1 μm
GOES-R FOR TEMPO AOD AND GOES-R CLOUD
MASK FOR TEMPO CLOUD SCREENING**

H3. TEMPO/GOES-R Synergy – (Shobha Kondragunta, Pubu Ciren)

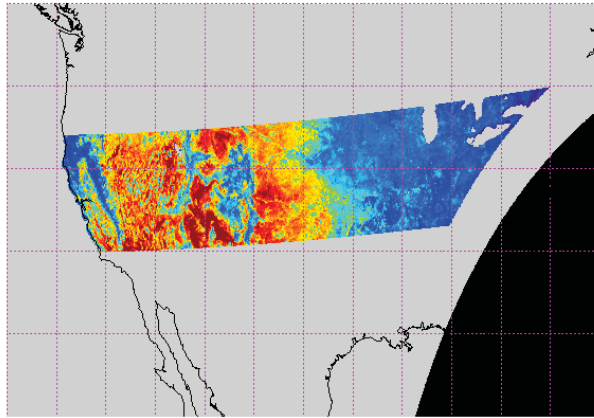
(a) Surface reflectance at 2.13 μm

July 15, 2012, UTC=19:00, $\sim 35^\circ\text{N}$ - 45°N

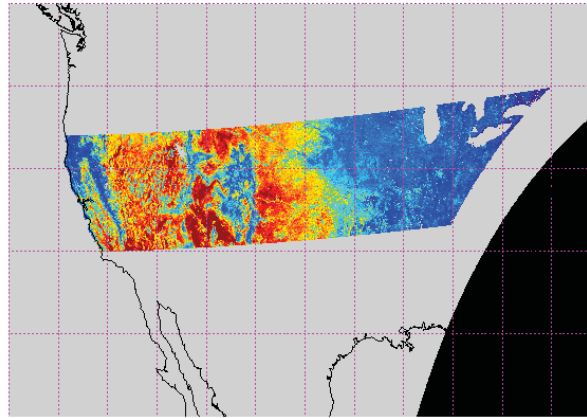
GOES-R (West, 135°W)

GOES-R remapped to TEMPO

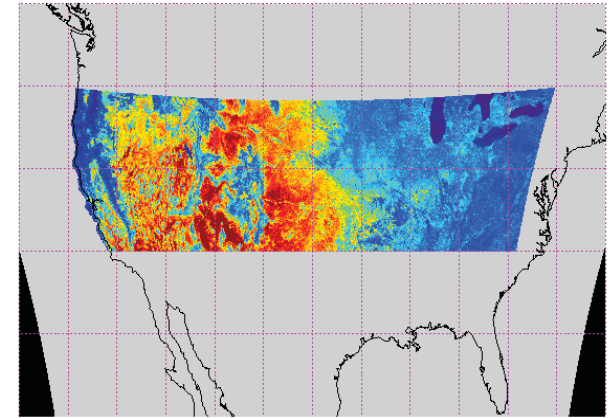
TEMPO (100°W)



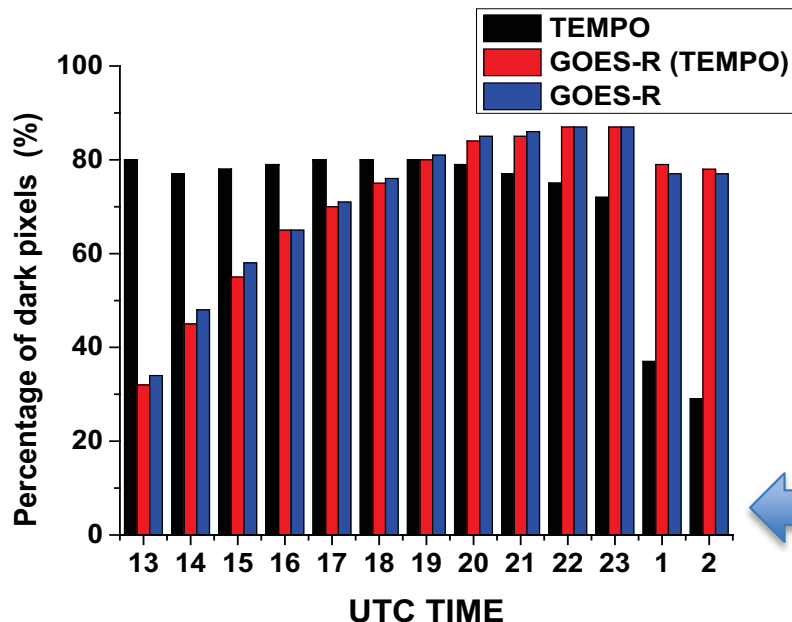
Surface Reflectance (2.13 μm) UTC=19
0.00 0.05 0.10 0.15 0.20 0.25 0.30



Surface Reflectance (2.13 μm)
0.00 0.05 0.10 0.15 0.20 0.25 0.30



Surface Reflectance (2.13 μm)
0.00 0.05 0.10 0.15 0.20 0.25 0.30



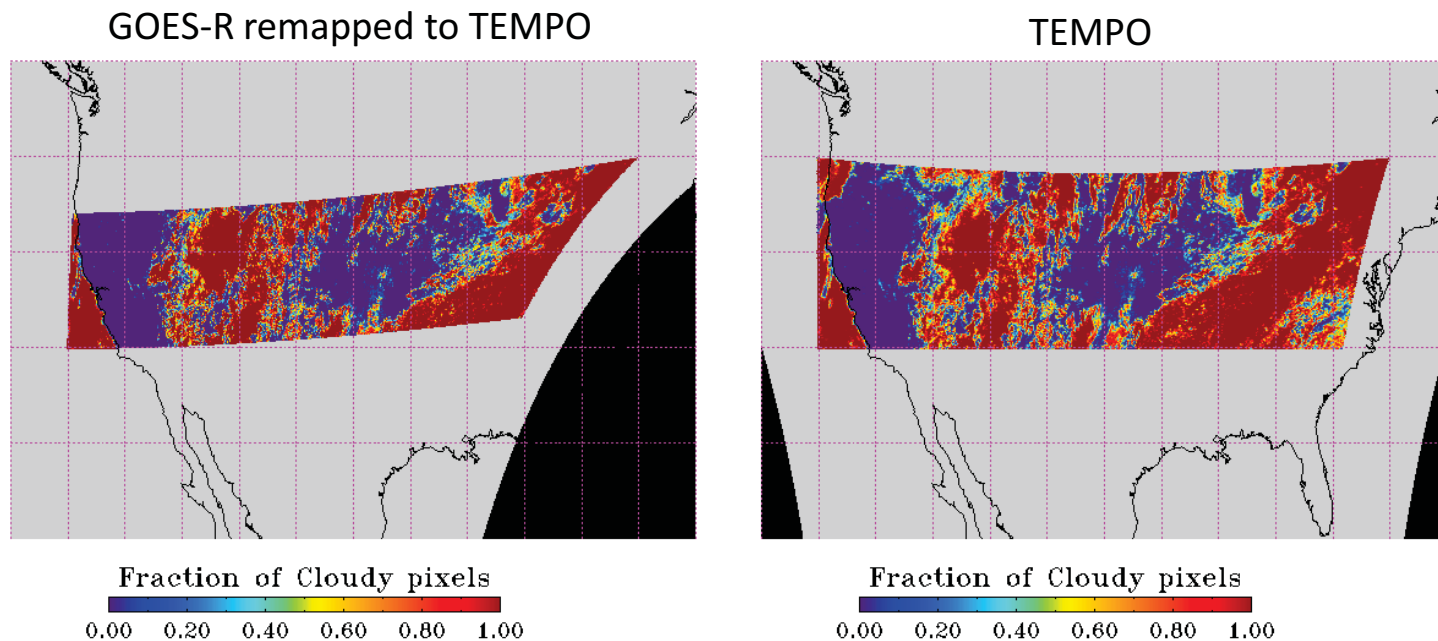
- GOES-R (west) and TEMPO do not overlap over eastern part of US and Atlantic Ocean.
- Synergic use of GOES-R is possible by providing surface reflectance at 2.13 μm for TEMPO aerosol retrieval (Dark Target) over portion of eastern, middle and western part of U.S.
- Observations in the early morning and later afternoon need to be avoided. Only hours close to noon time are favorable (for Lambertian surface)

H3. TEMPO/GOES-R Synergy – NESDIS group:

(b) GOES-R cloud mask for TEMPO

- MODIS 1km cloud mask (MOD35) was mapped into GOES-R (West) first then remapped GOES-R to TEMPO grid between latitude band from $\sim 35^{\circ}\text{N}$ to 45°N
- Fraction of cloudy (confident and probably cloudy) pixels calculated

July 15, 2012



- Cloud mask information from GOES-R observations seems to be sufficient for TEMPO

H3. TEMPO/GOES-R Synergy (Alexei Lyapustin, Sergey Korkin)

(1) Estimate error in using GOES-R (E) 2.1 μ m BRDF for TEMPO (2) Estimate RMSE of AOD retrieval due to the BRDF error

SNR=10

SNR=30

SNR=10

SNR=30

RMSE AOD, Summer, July 11

RMSE AOD, Winter, December 2

TEMPO at 120°W

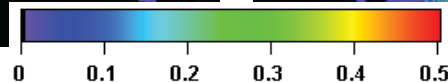
TEMPO at 120°W

TEMPO at 105°W

TEMPO at 105°W

TEMPO at 75°W

TEMPO at 75°W



- Over dark surfaces, the 2.1 μ m BRDF from GOES-R (East, 75°W) model can be used for TEMPO aerosol retrieval regardless of TEMPO's parking longitude
- Over central-eastern USA, the AOD RMSE based on GOES-R BRDF is expected to be < 0.05 (at 0.47 μ m). Over western USA the error is larger but the Dark Target (DT) algorithm is also not applicable

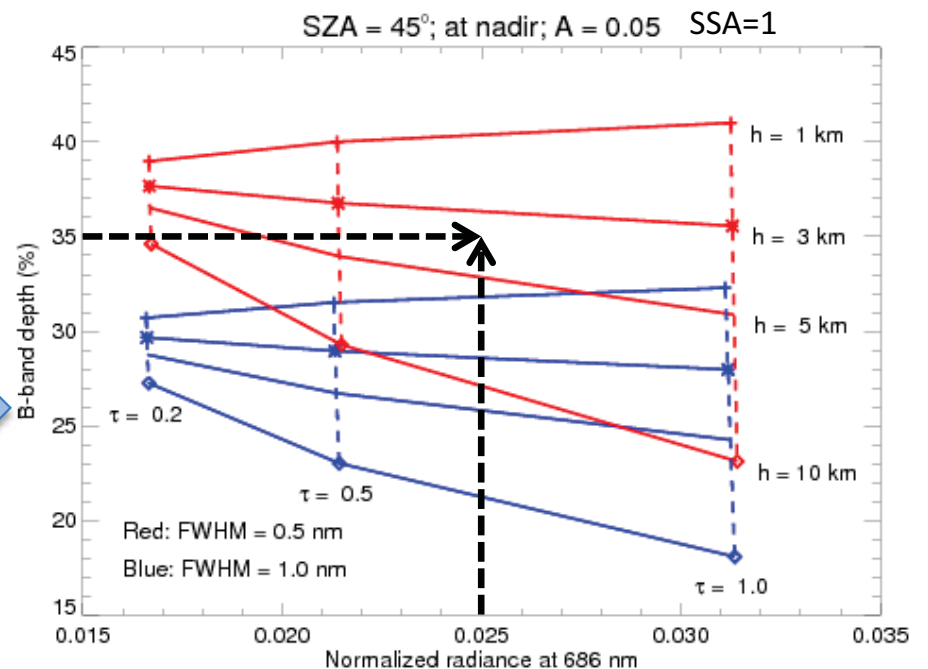
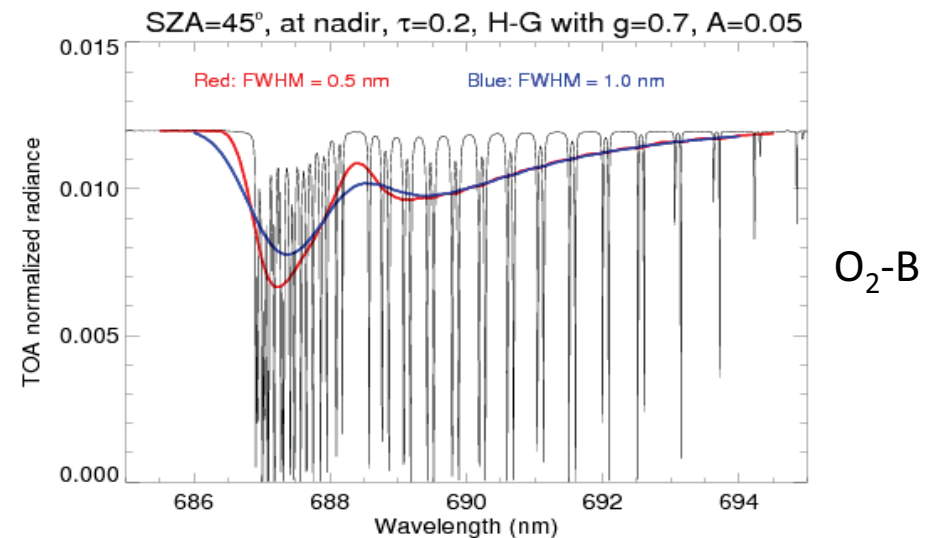
POSSIBILITY OF RETRIEVING AEROSOL HEIGHT OVER LAND USING O₂-B AND O₂- γ BANDS

H4. Aerosol height from O₂-B and O₂-γ (Alexander Vasilkov, Joanna Joiner)

- Radiative transfer simulations
 - LIDORT code: line-by-line O₂ absorption, TOA radiance with Gaussian response, FWHM=0.5, 1.0
 - Aerosol: 1-km thick layer at different plume top height of 1-10 km, AOD=0.2, 0.5, 1.0, SSA=0.8, 0.9, 1.0
 - Surface albedo: A=0.05, 0.1

- If SSA is known, the aerosol plume height and optical depth may be derived from measurements of the band depth and continuum reflectivity at 686 nm
- However, including additional uncertainties in chl fluorescence and surface pressure will increase the error for aerosol height

Simulated TOA spectral reflectivity



CONCLUSIONS

- Spatially, TEMPO alone (4x2 km) will have lower retrieval availability than GEO-CAPE (1x1 km) by 33% in the morning (10:30 am) by using MODIS cloud masks
- Temporally, TEMPO will have reduced AOD retrieval availability in partial cloudy scene
- AOD quality from TEMPO and GEO-CAPE is still under evaluation
- Synergy between TEMPO and GOES-R is very helpful in terms of (1) utilizing the extended spectral range for retrieving TEMPO AOD at visible wavelength and (2) using GOES-R cloud mask for TEMPO cloud screening under certain conditions
- O₂-B band shows promising sensitivity for aerosol height retrieval for both GEO-CAPE and TEMPO, but additional uncertainties need to be considered

Bottom line: GEO-CAPE measurement requirements, as defined in STM and studied by the AWG, are not 100% met by TEMPO alone.

HOWEVER...

- With the TEMPO selection and the outcome from the recent GEO-CAPE workshop (May 21-23, 2013), the reality tells us that we should focus on achieving GEO-CAPE aerosol objectives by the synergy between TEMPO and GOES-R
 - GOES-R: MODIS wavelength range, high pixel res, cloud mask, good for MODIS-like dark target land and ocean retrievals
 - TEMPO: UV-Vis, complementary to GOES-R for retrieving AOD over bright surface and providing AI
 - Combo: more aerosol retrieval quantity and coverage, with possibility of retrieving SSA and aerosol height using GOES-R AOD
 - Possibility of having a consistent, independent retrieval algorithm from the TEMPO-GOES-R combined spectral range (UV to IR)
- The GEO-CAPE Aerosol Working Group will shift the focus to the synergistic study